A COMPARISON OF POST-CYCLE ERGOMETRY OXYGEN CONSUMPTION BETWEEN LEAN AND OBESE WOMEN

By

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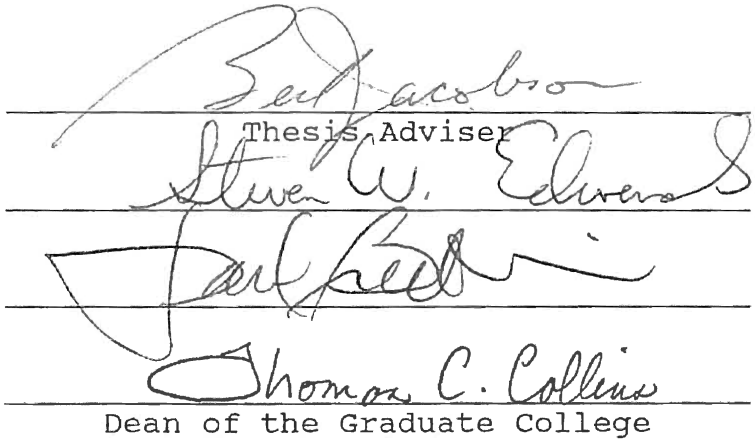

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I dedicate this project to my parents, the two people who have always believed in me. Special gratitude and love is expressed to my wife, Wendy, for her continual support and encouragement. I want to thank Don Buggln, Bert Jacobson, and Steve Edwards for their invaluable statistical help.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Obesity is a term that denotes "excessive fat." According to Cooper (1982) over 110 million men and women in America are "too fat" and should lose excess weight. Katch and McArdle (1988) estimate that 60 to 70 million adults are "too fat." Obesity is a health hazard which contributes to a variety of disorders and diseases and can lead to premature death (Matthews and Fox, 1981). Obese individuals often suffer from economic and social discrimination, poor body image, and depressed self-image (American Journal of Public Health, 1980).

Current theory states that excessive fat stores represent an imbalance between energy intake and energy expenditure (Katch and McArdle, 1988). Inactivity and a diet high in fat are the two primary causes of this imbalance. Many factors may influence an onset or predisposition to obesity. However, the specific cause of obesity, whether it be one or a number of factors, is the subject of great debate.

A person's heredity has been shown to be a primary factor in the onset of obesity (Katch and McArdle, 1988). Early childhood lifestyle habits can also be a

determinant. Research has suggested that differences in specific factors such as dietary induced thermogenesis (Devlin and Horton, 1986) and resting body metabolism (Segal et al., 1985) may cause a person to have a predisposition to obesity. However, attempts have failed to prove that obese people habitually eat more than lean people and that the obese have a lower resting metabolism or more efficient absorption of energy from food than lean people (Blaza and Garrow, 1982).

In recent years there has been considerable investigation into the suggested reasons for the onset and perpetuation of obesity. Numerous researchers have investigated whether or not obese individuals have certain physiological inhibitors which hinder energy expenditure as compared to lean individuals. Webb (1985) failed to show any significant differences between the lean and overweight with the exception of dietary-induced thermogenesis. Segal et al. (1987) found that the effect of exercise on dietary-induced thermogenesis is different in obese people as compared to lean and dependent on its timing in relation to food consumption.

The production of heat by humans is a by-product of energy metabolism. Intake of food enhances production of energy due to the increased activity of the digestive system. Energy expenditure is also increased due to exercise and daily activities which require greater oxygen uptake. Aerobic exercise dramatically increases energy

expenditure; however, energy expenditure declines after exercise (Katch and McArdle, 1988). Elevated post-exercise oxygen consumption, referred to as excess post-exercise oxygen consumption, is a phenomenon not altogether agreed upon. It has long been assumed that resting metabolism will remain elevated long after exercise (Gaesser and Brooks, 1984), even though this assumption has only proven to be true under certain conditions (Poehlman and Horton, 1989; Freedman-Akabas et al., 1985; Maehlum et al., 1986).

Uncovering the mystery of obesity has been a lifetime objective for many investigators. The weight loss business is a multi-billion dollar industry because so many people desire to lose weight and are willing to pay for products or services that claim to provide quick, positive results. Explanation of why some people have such a difficult time losing weight remains a mystery. Finding practical and credible answers for people who struggle with an inability to lose weight is a difficult yet worth-while challenge.

There have been numerous studies on energy expenditure during the post-exercise stage involving a variety of subjects. An impairment in the obese individual's energy system has been noted during specific conditions (Segal and Gutin, 1983). Presently, there are very few studies known to the researcher where effect of excessive body fat on the post-exercise oxygen consumption period has been analyzed (Segal et al., 1987; Segal et al., 1985). It is certain

that exercise raises the metabolism; however, if excess fat hinders the body's ability to expend energy after exercise, new methods of treatment and adaptive exercise programs could be devised to accommodate for this impairment. This knowledge could also help explain the difficulty some people have while trying to lose weight.

Statement of the Problem

The problem of this study was to investigate the post-cycle ergometry oxygen consumption in lean and obese females throughout the first 60 minutes of recovery. The subjects were: (1) trained and untrained women from 30 to 40 years of age, (2) given dietary and activity guidelines to follow prior to the testing, and (3) measured for oxygen consumption for 60 minutes post-exercise.

Hypotheses

This study attempted to determine if the excess post-cycle ergometry oxygen consumption of obese women is significantly less than lean women under the same conditions. The following hypotheses were tested:

HO_1: There is no significant difference between obese and lean women in absolute oxygen consumption (ml/min) at 15, 30, 45 and 60 minutes post-cycle ergometry.

HO_2: There is no significant difference between obese and lean women in weight adjusted oxygen consumption (ml/kg/min) at 15, 30, 45 and 60 minutes post-cycle

ergometry.

Delimitations

The following were the delimitations of this study:

1. All testing was administered at the Human Physiology Lab of Fit-for-Life, an affiliate of Northeast Georgia Medical Center.

2. The total number of subjects volunteering for the study was 16.

3. All subjects had these characteristics:

    a. 30 to 40 years of age,

    b. female,

    c. non-smoker (nor previous history of),

    d. non-diabetic,

    e. less than 25 percent body fat or greater than 35 percent body fat,

    f. no significant type 1 risk factors as defined by the American College of Sports Medicine (Appendix E).

4. Body fat was determined utilizing a five site skinfold measurement.

Limitations

This study was subject to the following limitations:

1. Subjects were asked to follow these dietary and activity directions:

    a. a normal meal was to be eaten without

alcohol or dessert consumption the evening prior to the test,

b. no heavy physical activity was to be performed 48 hours prior to testing nor exercise 24 hours prior to the test,

c. subjects were requested to eat no food nor drink any caffeine during the morning of the test.

2. All subjects were tested using a cycle ergometer regardless of their comfort or specific exercise training.

3. After the maximal stress test, subjects were not allowed to cool down.

Assumptions

For the purposes of this study, the following assumptions were accepted by the researcher:

1. Subjects correctly followed all dietary and activity instructions.

2. The resting values for oxygen consumption were correct for each subject.

3. Subjects gave a maximal effort on the stress test.

4. Body fat analysis was accurate, utilizing a five site skinfold test.

Definitions

The following are terms used in this study:

Thermogenesis - facultive heat production; the energy produced by the body.

Obesity - body fat at or above 35 percent for females and at or above 25 percent for males.

VO_2 - oxygen uptake volume.

Absolute oxygen consumption - the amount of oxygen utilized determined in ml/min.

Weight adjusted oxygen consumption - the amount of oxygen utilized determined by dividing an individuals body weight (kilograms) into absolute oxygen consumption and reported in ml/kg/min.

CHAPTER II

LITERATURE REVIEW

Introduction

Investigators continue to seek reasons to explain the causes of human obesity. One area that has received attention has been energy expenditure during and after exercise. Energy expenditure during exercise has been well documented for almost every activity. However, interest in post-exercise energy expenditure has recently been renewed due to mechanical and computer development, making oxygen uptake measurement more practical. The study of oxygen uptake variability after exercise is better understood upon study of the following: (1) Impaired Thermogenesis, (2) Resting Metabolic Rate, and (3) Excess Post-exercise Oxygen Consumption.

Impaired Thermogenesis

Thermogenesis is defined as facultive heat production (James and Trayhurn, 1981). The biological make-up of the human requires a thermogenic response from physiological activity. Heat is produced when the body shivers, sleeps, moves, or digests foods. This process allows the human body to adapt to changes in climate, produce heat to the system

when needed, and expend energy upon request.

Impaired thermogenesis is a blunted capacity for increased energy expenditure in response to certain stimuli, posing questions toward the current treatments of obesity (Segal et al., 1987). There seems to be considerable conflict regarding the significance of this phenomenon and its importance to the onset and perpetuation of obesity. Segal and Gutin (1983) showed that the rise in metabolic rate after ingestion of a meal, cold exposure, and the combination of a meal plus physical exercise is significantly smaller in obese than lean humans. One study observed the thermic effect of food significantly blunted in the obese at rest, during exercise, and post-exercise (James and Trayhurn, 1981). This would suggest that individuals who have poor control of body weight have a blunted thermogenic response to eating, which may, over a period of years, contribute to the accumulation of body fat. Devlin and Horton (1986) noted similar findings. They suggested that impaired thermogenic responses to feeding may be one mechanism for the maintenance, if not cause, of obesity. Segal et al. (1987) found blunted thermogenesis may be related to impaired glucose tolerance, a frequent complication of obesity.

Specific factors which may cause impaired thermogenesis have not been agreed upon, nor has the significance of impaired thermogenesis to obesity been determined. Some reports suggest that obesity may effect energy expenditure

and the thermic effect of food (James and Trayhurn, 1981; Segal and Gutin, 1983). While there seems to be substantial support for the theory that impaired thermogenesis plays a role in the onset and perpetuation of obesity, it has been argued that body weight is not a significant factor in blunted thermogenesis. Segal et al. (1985) matched lean and obese men of similar body weight. Their findings demonstrated that absolute energy expenditure is greater for the obese even though the obese had significantly smaller thermogenic responses to a variety of stimuli.

Higher body weight of obese people effects the comparison of energy production data in studies measuring energy expenditure during physical activity. Similar studies of obese subjects showing a blunted thermogenic response to food and exercise before ingestion of a meal have led researchers to hypothesize on the effect body fat has on energy expenditure as a whole. One such study showed that excessive weight actually increases energy expenditure during physical work (Blaza and Garrow, 1983). When the effect of excess weight is controlled for, obesity is associated with reduced energy expenditure and a diminished capacity for thermogenesis, compared to lean control subjects (Segal et al., 1985). Explanation for this occurrence remains unclear. Although Segal et al. (1985) indicated that body weight was not a major determinant of thermogenic response, they did not clarify the role of body composition. Two studies suggest that the proportion of fat

tissue is a more important factor than usually recognized (James et al., 1978; Ravussin et al., 1982). Further research demonstrated that body composition is a significant determinant of thermogenesis and the capacity for thermogenesis is blunted in overly fat compared with the overly muscular men (Segal et al., 1985).

Resting Metabolic Rate

Energy expenditure reflects the body's heat production and is determined indirectly by measuring oxygen consumption. The three components which directly determine energy expenditure are resting metabolic rate (RMR), dietary thermogenesis, and physical activity (Katch and McArdle, 1988). Resting metabolic rate is determined by measuring oxygen consumption in the post-absorptive state. Normal range values for men and women are between 160 and 290 ml oxygen/minute, the equivalent of 0.8 to 1.45 kcal each minute. For convenience of calculating kcal from oxygen consumption, one liter of oxygen is equivalent to five kcal (McArdle, Katch, and Katch, 1986). An average 70 kg male will have a resting energy expenditure of approximately 1500 kcal/day or 60 percent to 75 percent of total daily energy expenditure (Poehlman et al., 1989; Katch and McArdle, 1988). Resting energy expenditure is five percent to ten percent lower in women than men because women generally have less fat free mass, the metabolically active tissue in humans (McArdle, Katch, and Katch, 1986).

Since the metabolic contribution of resting energy expenditure normally accounts for greater than two-thirds of daily energy expended, increase or decrease due to certain stimuli is of considerable importance, especially in the study of human obesity. Tremblay et al. (1986) reported a ten percent increase in resting energy expenditure in men who exercised regularly and noted an eight percent increase in resting energy expenditure among obese women after an eleven week exercise program. Among obese women, this would account for an increase of approximately 60 to 100 kcal expended each day, nearly one extra pound of energy expenditure each month. Whether the increase in resting energy expenditure was higher due to the residual effect of the last exercise bout or the continuous trained state was inconclusive.

Resting energy expenditure is substantially reduced following a low-calorie diet regimen. Results suggest a decrease in metabolically active lean tissue in the body after prolonged starvation and low calorie regimens (Tremblay et al., 1986). Nevertheless, exercise training which leads to a weight loss can increase resting metabolic rate per kilogram of fat free mass (Lennon et al., 1985).

Resting energy expenditure is strongly correlated with fat free mass and body weight (Tremblay et al., 1986). The more fat free mass individuals have the higher their resting energy expenditures (Forbes and Welle, 1982). When comparing obese and lean individuals, the mean resting

metabolic rate as expressed in absolute oxygen consumption has been found to be increased in the obese patients. This phenomenon can be explained by the fact that obese individuals usually have more fat free mass than lean people (Segal et al., 1985).

The full importance of resting energy expenditure's relationship to obesity has not yet been realized. While most research is motivated by a theory of low resting energy expenditure among the obese, James and Trayhurn (1982) pointed out:

> measuring only the resting metabolic rate in the obese is unlikely to help in understanding the pathogenesis of obesity.

On the other hand, a low energy expenditure could play a role in the energy imbalance that characterizes the dynamic phase of obesity (Ravussin et al., 1982).

Excess Post-exercise Oxygen Consumption

During exercise, oxygen consumption increases dramatically. The increased need for oxygen in the energy system has long been established. Oxygen debt, a term defined as the total amount of oxygen used after cessation of exercise, has been used to explain initial energy expenditure directly after exercise cessation and is often linked to energy expenditure two or more hours after exercise. The oxygen debt hypothesis has been used to explain post-exercise metabolism in a number of species. Its universal applicability has been challenged due to a

vast amount of contradictory results. Since lactate metabolism has not been linked directly with long term excess energy expenditure after exercise, no relationship has been established (Gaesser and Brooks, 1984).

Oxygen consumption during exercise has been shown to be higher in obese than lean individuals (James et al., 1978; Ravussin et al., 1982). Increased oxygen consumption is due to the increased work required to move heavy legs and to support body weight (Webb, 1985).

Excess post-exercise oxygen consumption, commonly referred to as EPOC, represents a majority of the recovery energy expenditure after exercise (Gaesser and Brooks, 1984). Research suggests that three phases exist to EPOC. The first phase is rapid, usually lasting 30 seconds to five minutes. The second component or phase is slower, usually lasting up to 40 minutes (Hagberg, Mullin, and Nagle, 1980). The final stage, known as the ultraslow phase, may last for many hours (Gaesser and Brooks, 1984). Krogh and Lindhard (1913) suggested that the slower component was related to lactate metabolism because its time course closely paralleled the fall in blood lactate. Since the role of lactate metabolism in the slow component of recovery oxygen consumption has not been linked with EPOC, more emphasis is now being centered on a temperature effect as a possible cause of this phenomenon (Hagberg, Mullin, and Nagle, 1980).

The specific factors responsible for EPOC are not agreed upon. Brehm and Gutin (1986) state:

> there exists no universally accepted explanation of the post-exercise metabolism phenomenon.

Many factors may be involved in stimulating respiration after exercise. The relative contribution of each of these factors is undoubtedly influenced by variables such as species, exercise training and duration, environment and state of training (Gaesser and Brooks, 1984).

The size and significance of EPOC and its contribution to energy balance is unclear and often misunderstood. After exercise, oxygen consumption quickly drops for two to five minutes and then assumes a more gradual decline to resting values (Brehm and Gutin, 1986). Freedman-Akabas et al. (1985) showed recovery oxygen consumption returning to non-exercise levels after only 40 minutes post-exercise. James and Trayhurn (1981) demonstrated that if work intensity was below 70 percent of maximum oxygen uptake, exercise duration had no effect on EPOC. Studies reporting insignificant EPOC utilized exercise protocols where intensity and duration were relatively low.

A credible amount of evidence supports the theory that EPOC remains elevated more than several hours. Brehm and Gutin (1986) noted that although recovery oxygen consumption was almost negligible at a 3.2 km/hr walk, recovery from maximal exercise intensities were significant, even three to four times as great as recovery from 3.2 km of jogging. An elevation in oxygen consumption post-exercise has been found significant six hours after a one hour aerobic class. Other tests have shown increased oxygen consumption levels up to

24 hours post-exercise (Brehm and Gutin, 1986). Earlier studies may have exaggerated the carryover effect of exercise on metabolic rate. Initial tests several decades ago showed energy expenditure to be heightened up to 36 hours post-exercise (Edwards, Thorndike, and Dill, 1935; Whipp, Bray, and Koyal, 1973). However, these tests' validity have been challenged because food intake was discounted. The great variation of the metabolic rate with daily changes in eating, stress, and activity continue to make measurements variable and interpretation difficult.

More evidence supporting the significance of excess post-exercise oxygen consumption has been demonstrated. One study showed that although subjects' oxygen consumption returned to normal levels several hours after exercise, a shift in energy metabolism was noted (Bielinski, Schutz, and Jequier, 1985). Lower r-values revealed a shift towards fat oxidation above control data. Thus, more fat was oxidized during the recovery phase post-exercise. Maehlum et al. (1986) noted this occurrence for 24 hours post-exercise and Bielinski, Schutz, and Jequier (1985) approximated an extra 24 grams of fat were used over a similar 17 hour period.

Physiologically, the biochemical basis for EPOC is not entirely understood. There are many factors which may play a part in recovery oxygen consumption. The amount each factor effects resting metabolic level is also uncertain. Mitochondrion is the site of oxygen consumption in the cell (McArdle, Katch, and Katch, 1986). The explanation of EPOC

may be found at the level of cellular organelle. Gaesser and Brooks (1984) suggest:

> It is very probable that the chemical and physical changes occurring in muscle cells during contraction which are necessary for increasing VO_2 and ATP production persist for some time after exercise cessation. Indirect control of mitochondrial respiration may include a variety of factors, including catecholamines, thyroxin, glucocorticoids, fatty acids, calcium ions, and temperature (Q10 effect).

Poehlman and Horton (1989) suggest that an increase in long-term EPOC may be related to the energy cost of replenishing glycogen stores. There is no doubt that after intense exercise (intensity > 70 percent VO_2 max) there is an oxygen debt which causes an initial elevation of oxygen uptake. Bahr et al. (1987) stated that the increased levels of catecholamines and increase in body temperature are more likely to be responsible for the majority of long-term EPOC. Maehlum et al. (1986) reported that catecholamines have been shown to increase the rate of the triglyceride, fatty acid cycle, thus increasing the need for oxygen. Furthermore, the mobilization of fat from adipose tissue reserves could have an even greater impact on EPOC. The factor responsible for the relationship between duration of exercise and EPOC may be the gradual increase in the dependence on fatty acids as a fuel as exercise duration increases (Bahr et al., 1987).

Temperature may play an even greater part in responsibility for EPOC (Gaesser and Brooks, 1984). Several studies reveal body temperature elevated one to two hours

post-exercise (Gaessar and Brooks, 1984; Poehlman and Horton, 1989). The extent to which temperature contributes to the post-exercise VO_2 may be related to the effects of elevated temperature on mitochondrial energetics. Elevated temperatures have been shown to increase nonconservative respiration and decrease phosphorylative coupling efficiency. Thus, more oxygen consumption would be required for a given amount of ATP to be synthesized (Gaesser and Brooks, 1984).

Generally stated, the more exercise disturbs the body's homeostasis, the greater its apparent effect on recovery metabolism (Poehlman and Horton, 1989). Variation in experimental design is the major contribution to the discrepancy over EPOC duration. Some protocols have subjects exercising at a normal pace which the average adult would safely handle (Freedman-Akabas et al., 1985; Brehm and Gutin, 1986; Pacy et al., 1985). Results from these experiments showed insignificant EPOC duration. High intensity and long duration protocols elicit longer duration and higher volume of oxygen uptake after exercise cessation (Bielinski, Schutz, and Jequier, 1985; Maehlum et al., 1986). One study required subjects to exercise for 3 hours, an impractical amount for the normal person (Bielinski, Schutz, and Jequier, 1985). Significant amounts of EPOC have only been found in protocols where both intensity and time are high and long, respectively (Poehlman and Horton, 1989).

The most significant findings from research which effect the direction and procedures of the present study are: (1) there are circumstances where obesity has been determined to impair thermogenesis; (2) resting metabolic rate is a significant contribution to overall energy expenditure; and (3) post-exercise oxygen consumption remains significantly elevated for over three hours when subjects participate in high intensity, long duration exercise protocols.

CHAPTER III

METHODS

Subjects

Sixteen subjects were chosen from volunteers who met the following predetermined physical requirements:

1. 30 to 40 years of age,
2. female,
3. non-smoker (nor history of smoking),
4. non-diabetic,
5. constant bodyweight for two months prior to test,
6. less than 25 percent body fat or greater than 35 percent body fat,
7. no significant type I risk factors as defined by the American College of Sports Medicine (Appendix E).

Eight subjects were assigned to the obese group and eight were assigned to the lean. All subjects were in apparently good health and most exercised at least two days each week. All volunteers filled out health history forms to be reviewed for participation (Appendix B). Subjects' physicians were consulted prior to testing.

Following verbal consent, subjects agreed to sign an informed consent document (Appendix A), as approved by the regulations specified by the Oklahoma State University

Institutional Review Board (IRB).

Preliminary Procedures

Subjects were asked to:

1. Refrain from heavy work or activity 48 hours prior to the test.

2. Refrain from any exercise 24 hours prior to the test.

3. Refrain from consumption of alcohol or desserts the evening before the test.

4. Eat a normal meal the evening before the test, no later than 7 p.m.

5. Refrain from food or non-water drink the morning of the test.

6. Refrain from excessive movement the morning of the test (i.e. walking up stairs, cleaning house, etc...).

All subjects were briefed as to the procedures and objectives of the investigation prior to the experiment. The tests were conducted in a quiet, cool room. Instructions and motivation were given during the maximal stress test and throughout the data collection period.

Procedures

Body Fat Percentage

Each of the subjects was tested for body fat composition utilizing Harpenden Skinfold Calipers. A sum of five measurements was used. The researcher acknowledges

that there is usually a plus or minus three percent to five percent error in body fat prediction when utilizing the skinfold method compared to hydrostatic weighing (McArdle, Katch, and Katch, 1986). Skinfold calibration was done by the investigator averaging three separate measurements.

Resting Metabolic Rate

Upon arrival to the Human Performance Lab in the morning, each of the subjects was asked to relax in a comfortable chair. A Medigraphics 2001 Metabolic Cart was utilized for all breath analysis. A small low-resistance two-way valve with a dead space of 15 ml was used for all resting measurements (before and after exercise). After 20 minutes of rest, each subject practiced breathing through a mouthpiece attached to the hoses leading to the metabolic measurement cart. Subjects were instructed to become accustomed to breathing at a normal rate through the mouthpiece before breath analysis began. After approximately three minutes, a nose clip was properly placed and a 20 minute breath measurement was taken. Subjects were left alone. Each was asked not to sleep. Measurement of resting metabolic rate protocol was consistent with McArdle, Katch, and Katch, (1986).

Exercise Test and Recovery Oxygen Consumption

After resting oxygen uptake values were determined

(Table I), each subject read and signed a Maximal Graded Exercise Test Consent Form (Appendix D). A Case 12 EKG machine with 12 leads was used to monitor subjects. Preparations for an accurate test included metabolic cart calibration, attachment of electrodes for EKG monitoring, placement of headgear to hold mouthpiece and hosing securely during exercise, and proper seat height adjustment for each individual. Seat height was set at the level where each subject could almost fully extend their legs on the downstroke of each revolution (approximately five percent to ten percent from full extension). A large two-way valve for breath analysis (dead space 100 ml) was used for less restrictive breathing during exercise. After verbal instructions and motivation were given, each subject participated in a maximal graded exercise test utilizing a Bodyguard 990 cycle ergometer. The protocol consisted of a 25 watts increase every three minutes. The American College of Sports Medicine suggests a protocol of 25 watts increases every two minutes. This protocol was altered by adding one minute to each stage. Each subject began pedalling with no load applied. At three minutes, the work load was increased to 25 watts and continued to be increased by 25 watts every three minutes thereafter until each subject reached voluntary exhaustion. Ventilation and gas exchange parameters were measured breath-by-breath using a computerized system (Medical Graphics, system 2001). During exercise subjects breathed through a low resistance non-

rebreathing valve (Hans Rudolph, dead space: 100 ml) which was held by a headpiece. Expired gases were sampled at the mouthpiece and analyzed for CO_2 and O_2 concentration. Input of pre-test and exercise test information was performed by this investigator. Calibration of gas analyzers was performed with precision analyzed gas mixtures. Calibration of the equipment was performed prior to testing and after every test. Breath-by-breath gas exchange parameters underwent analog to digital conversion and were compiled and averaged by a host computer.

Upon reaching exhaustion, each subject stopped pedalling and remained seated on the bike. Expired gasses continued to be monitored during the first 15 minutes post-exercise. At 15 minutes post-exercise, all apparatus was removed to allow subjects to relax, go to the restroom, or drink some water. No other movement was allowed. After a brief (two to three minutes) break, subjects were instructed to be seated for the remainder of the test. Oxygen consumption was measured at the following post-exercise time intervals: 10 to 15 minutes, 25 to 30 minutes, 40 to 45 minutes, and 55 to 60 minutes.

Data Analysis

Net post-exercise oxygen consumption above resting was calculated by subtracting each subject's resting oxygen uptake from their post-exercise oxygen uptake values at all four time intervals. These values were calculated in

absolute oxygen consumption (ml/min) and weight adjusted oxygen consumption (ml/kg/min). Two separate 2 x 4 two-way repeated measures analyses of variance were used to analyze the results. These analyses use group, lean or obese, and net oxygen consumption at time intervals of 15, 30, 45 and 60 minutes post-exercise. Significant group x time F ratios from the analyses of variance were followed by post hoc comparisons. Subject characteristic means were tested between groups using the students t-test. For all statistical analyses the 0.05 level of significance was used.

CHAPTER IV

RESULTS AND DISCUSSION

Characteristics of Subjects

Sixteen apparently healthy females participated in this study. Eight subjects comprised the lean group, defined as individuals < 25 percent body fat. Eight subjects were assigned to the obese group, defined as > 35 percent body fat. Absolute body weight, body fat percentage, lean body weight and fat weight were significantly greater for the obese group at $p < 0.005$. Tables I and II show individual and group characteristics, respectively. Table I gives the absolute and weight adjusted oxygen uptake values for each subject during rest and maximal exercise. Absolute resting oxygen uptake rates were found to be significantly greater for the obese group at $p < 0.005$. Although absolute VO_2 max in ml/min was not significant between the two groups, the lean group had significantly ($p < 0.005$) greater weight adjusted VO_2 max. Age was not significantly different.

Table IV shows the individuals' differences between post-exercise oxygen uptake and resting oxygen uptake at each time interval. These differences are defined as net EPOC.

TABLE I

SUBJECT CHARACTERISTICS

Subject	Age	Weight (kg)	Body Fat%	Lean Weight(kg)	Fat Weight(kg)	Resting VO_2 (ml/min)	Resting VO_2 (ml/kg/min)	VO_2 max (ml/min)	VO_2 max (ml/kg/min)
Lean									
1	35	53.2	19.7	42.8	10.4	136	2.6	2179	41.0
2	32	58.2	12.0	51.2	7.0	215	3.7	2545	44.0
3	36	55.4	17.5	45.7	9.7	166	3.0	2110	39.2
4	34	55.4	17.0	46.0	9.4	208	3.8	3344	42.0
5	37	57.7	17.7	47.5	10.2	173	3.0	2296	40.0
6	33	55.9	25.0	41.4	14.4	148	2.7	1468	26.0
7	33	61.4	20.7	48.7	12.7	193	3.2	2087	34.0
8	31	56.4	26.0	41.8	14.6	164	2.9	1763	31.0
$\bar{X}$	33.87	56.7	19.575	45.637	11.062	175.375	3.1125	2224	37.15
s	±1.88	±1.54	±4.61	±3.48	±2.74	±27.95	±0.43	±558	±5.85
Obese									
1	39	83.2	35.0	54.1	29.1	254	3.1	1853	22.0
2	30	100.0	39.0	61.0	39.0	241	2.4	2153	22.0
3	37	84.0	31.7	57.4	26.6	270	3.2	2090	25.0
4	33	76.0	28.0	54.7	21.3	238	3.1	1655	22.0
5	33	78.2	38.5	48.2	30.0	314	4.0	2505	32.0
6	32	85.4	37.1	53.7	31.7	227	2.7	1655	19.0
7	34	83.2	38.5	51.2	32.0	199	2.4	1600	19.0
8	31	85.0	39.0	51.8	33.2	289	3.4	2010	23.0
$\bar{X}$	33.62	84.375	35.85	54.0125	30.362	254	3.0375	1940.125	23.0
s	±3.02	±7.14	±4.05	±3.92	±5.14	±36.37	±0.537	±311.13	±4.14

TABLE II

GROUP CHARACTERISTICS

	Lean (n=8)	Obese (n=8)	P
Age	33.875 ± 1.88	33.625 ± 3.02	NS
Weight (kg)	56.7 ± 1.54	84.375 ± 7.14	<0.005
Percent Fat	19.575 ± 4.61	35.85 ± 4.05	<0.005
LBM (kg)	45.637 ± 3.48	54.0125 ± 3.92	<0.005
Fat Wt. (kg)	11.062 ± 2.74	30.362 ± 5.14	<0.005
Maximum Aerobic Power			
VO_2 (ml/min)	2224.00 ± 558	1940.125 ± 311.13	NS
(ml/kg/min)	37.15 ± 5.85	23.0 ± 4.14	<0.005
Resting Oxygen Uptake			
VO_2 (ml/min)	175.374 ± 27.95	254 ± 36.37	<0.005
(ml/kg/min)	3.1125 ± .43	3.0375 ± .537	NS

Results for Absolute Oxygen Consumption

Statistical analysis (Table III) indicated no significant difference ($p < 0.05$) between the lean and obese groups at 15, 30, 45 and 60 minutes post-exercise in absolute oxygen consumption (ml/min).

Results for Weight Adjusted Oxygen Consumption

Statistical analysis indicated no significant difference ($p < 0.05$) between the lean and obese groups at 15, 30, 45 and 60 minutes post-exercise in weight adjusted oxygen consumption (ml/kg/min).

TABLE III

REPEATED MEASURES
ANOVA TESTS

ANOVA Test 1. Net VO_2 in ml/min

Source	SS	DF	MS	F
Group	11664.0	1	11664.0	1.31
Error	124628.94	14	8902.07	
Time	23334.0	3	7778.020	3.45*
Time*Group	973.875	3	324.625	0.14
Error	94625.062	42	2252.977	

ANOVA Test 2. Net VO_2 in ml/kg/min

Source	SS	DF	MS	F
Group	7.09556	1	7.09556	4.05
Error	24.52348	14	1.75168	
Time	5.18469	3	1.72823	3.04*
Time*Group	0.032611	3	1.0870	.19
Error	23.88751	42	0.56875	

*$p<0.05$

TABLE IV

NET EXCESS POST-EXERCISE OXYGEN UPTAKE
IN ML/MIN AND ML/KG/MIN

Subject	15 minutes		30 minutes		45 minutes		60 minutes	
	ml/min	ml/kg/min	ml/min	ml/kg/min	ml/min	ml/kg/min	ml/min	ml/kg/min
Lean								
1	140	2.631	144	2.706	113	2.124	50	0.939
2	258	4.433	15	0.258	-5	-0.086	24	0.412
3	126	2.274	32	0.578	59	1.064	64	1.155
4	44	0.794	1	0.018	-33	-0.595	-29	-0.523
5	49	0.849	25	0.433	8	0.139	16	0.277
6	71	1.270	125	2.236	57	1.020	77	1.377
7	7	0.114	58	0.945	120	1.954	13	0.217
8	-20	-0.355	68	1.200	48	0.851	66	1.170
$\bar{X}$	84.375	1.50125	58.5	1.04575	45.825	0.80887	35.125	0.628
s	±88.571	±1.55002	±51.89	±0.96294	±54.175	±0.95414	±35.462	±0.64285
Obese								
1	-8	-0.096	41	0.493	65	0.781	31	0.372
2	96	0.960	128	1.280	37	0.370	102	1.020
3	18	0.214	-99	-1.178	-78	-0.928	-98	-1.167
4	97	1.276	17	0.224	32	0.421	51	0.671
5	56	0.716	-40	-0.511	-13	-0.166	-89	-1.138
6	-1	-0.001	-17	-0.199	8	0.094	-12	-0.140
7	162	1.947	57	0.685	120	1.442	51	0.613
8	85	1.000	61	0.718	31	0.365	36	0.423
$\bar{X}$	63.125	0.752	18.5	0.189	25.25	0.29737	9	0.08175
s	58.237	0.69531	69.975	0.78549	57.56	0.68939	70.59	0.82866

Discussion of Results

Statistical data revealed that oxygen consumption within 60 minutes of cycle ergometry is not significantly ($p < 0.05$) different between obese females and lean females. These findings do not reflect the conclusion of Segal et. al. (1985) who suggested that body composition is a significant determinant of thermogenesis. However, most research in this area has examined the thermogenic effects of food and exercise, as opposed to primarily exercise induced EPOC. The primary intent of this study was to eliminate possible factors which may cause an increase in EPOC while examining the post-exercise VO_2. According to the results of this study, body composition has little to do with the rate at which oxygen consumption returns to near resting values after exercise.

Statistical analysis revealed a significant ($p < 0.05$) difference between the groups in absolute and weight adjusted oxygen consumption over time. This significance has long been proven to be the normal response to exercise (McArdle, Katch, and Katch, 1986). Thus, no post hoc test was utilized.

Subject characteristics showed a significant difference ($p < 0.005$) between groups in absolute resting oxygen consumption yet no significant difference in absolute maximal oxygen consumption. The obese individuals had more fat free body weight than the lean individuals resulting in higher resting absolute oxygen consumption (Forbes and

Welle, 1982). Since the absolute VO_2 max values between the obese and lean groups were not significantly different, it is possible that higher body weights among the obese subjects caused a significantly lower weight adjusted VO_2 max ($p < 0.005$).

Type of protocol is a key factor in the study of EPOC. Since the motivation behind this study was to determine if the average obese female would be handicapped in weight loss efforts, choice of protocol may well be the primary reason for acceptance of the null hypothesis. Although this study did not show a significant level of EPOC, others have. Studies which have demonstrated high levels of EPOC required impractical protocols for unfit test participants. One researcher had subjects exercise vigorously for over 1 hour, sometimes at 70 percent VO_2 max (Maehlum et al., 1986). Few exercise specialists would expect these types of work-outs by overweight individuals; however, research shows that low-level exercise does not cause a higher EPOC. For these reasons, this study utilized a maximal stress test in an attempt to create greater EPOC as demonstrated by Brehm and Gutin, (1986). Due to the lack of time subjects had for testing and the inability some would have in maintaining a high level of exercise intensity for any length of time, the protocol was chosen to take each individual to their maximum level of exertion as slowly as possible and yet not to significantly fatigue leg muscles before maximum VO_2 levels were achieved. Although the data collected was within 90

minutes post-exercise, the results do not support the broad conclusion that exercise produces a prolonged thermogenic effect as evidenced by the near resting values of both groups at 60 minutes post-exercise (see Figures 1 and 2). As previously noted, the protocol used was not very long, approximately 12 to 25 minutes, and therefore would not be expected to illicit the metabolic disturbance required to cause significant EPOC.

Determination of resting metabolic rate may have been more reliable had more measurements been taken. Ideally, the subjects should have been tested on at least two consecutive mornings to determine their RMR. However, due to time demands placed on the subjects, such as jobs, children and family care, only one measurement was feasible. The researcher did note that most of the women were able to relax and show steady oxygen consumption rates. Several of the females' resting VO_2 measurements did appear to be elevated. These findings may have been due to subject apprehension or mouthpiece discomfort.

The lean subjects were noticeably more relaxed and confident during the testing. Whether this finding was due to greater familiarity with a cycle ergometer or higher fitness levels was not determined. The lean subjects had significantly ($p < 0.005$) higher weight adjusted VO_2 max values than the obese. However, as Tremblay et al. (1986) and Akabas et al. (1985) noted, higher VO_2 max does not effect recovery time after exercise.

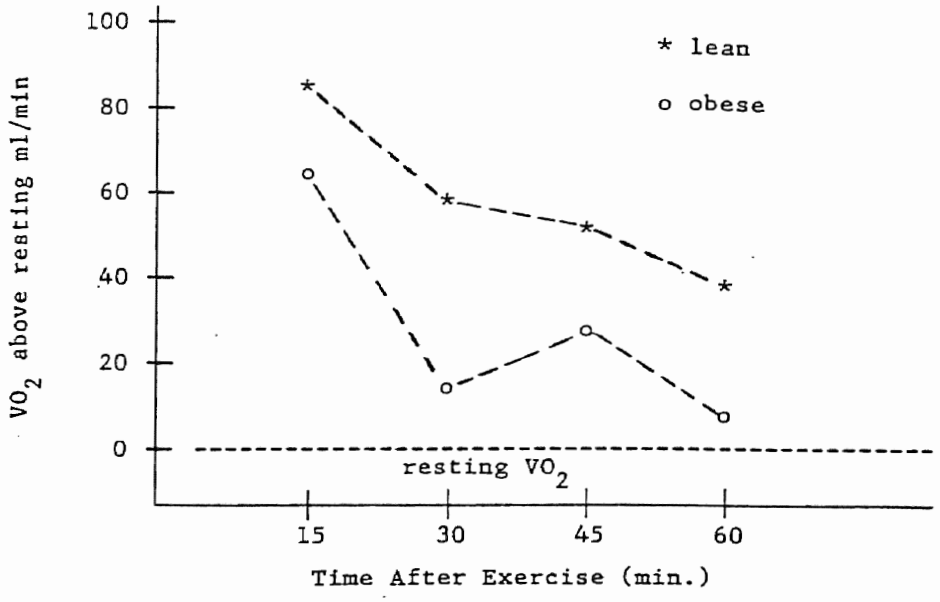

Figure 1. Net post-exercise absolute VO_2 above resting in lean and obese women.

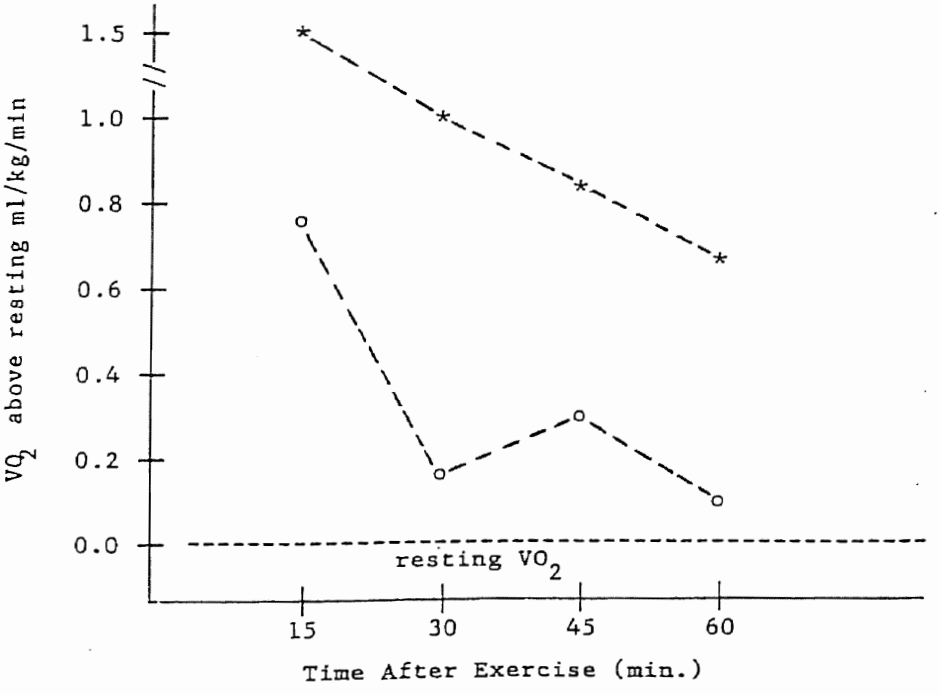

Figure 2. Net post-exercise weight adjusted VO_2 above resting in lean and obese women.

Several of the subjects had lower than resting values during the four intervals measured post-exercise. Two reasons may be given for these negative net energy expenditure values. First, subjects' resting values may have been elevated due to apprehension or discomfort during resting oxygen uptake measurement. After strenuous exercise, subjects relaxed as they became accustomed to the mouthpiece. Second, the negative values as expressed in Table IV are quite small, nearly equivalent to resting. It is normal to find post-exercise oxygen values hovering around the resting level, especially after 40 minutes (Brehm and Gutin, 1986).

Since the time of data collection was limited to 60 minutes, the researcher determined that r-values would not be of statistical use. However, in studies over three to 24 hours, r-values have been shown to remain lower many hours after an exercise bout of long duration and high intensity (Bielinski et al., 1985).

The results of this study indicate that there is no difference between the recovery oxygen consumption among obese and lean women after maximal exercise on a cycle ergometer. It is recommended that all obese individuals follow the exercise and diet guidelines as stated by the American College of Sports Medicine (Guidelines for Exercise Testing and Prescription, 1986). This study bears no evidence that the obese have an impaired energy expenditure system with regards to exercise recovery.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The aim of this study was to determine if there is a difference between the post-cycle ergometry oxygen consumption in lean and obese women during the first 60 minutes of recovery from exercise. Significant findings would suggest exercise-induced impaired thermogenesis among the obese. Sixteen females participated in a cycle ergometer maximal graded exercise test and were then measured for oxygen consumption at four separate time intervals post-exercise.

Findings

Statistical analysis revealed that there was no significant difference ($p < 0.05$) between lean and obese groups in oxygen consumption at 15, 30, 45 and 60 minutes post-exercise. These results were supportive of similar research where exercise did not have a causal effect on impaired thermogenesis among obese men (Segal et al., 1987).

Conclusions

No significant ($p < 0.05$) difference was found to accept the alternative hypothesis that obese women do not expend as much energy after exercise as lean women. Proof of an exercise-induced energy expenditure impairment among the obese would promote research for the development of new treatments for obesity. This study did not demonstrate any such impairment. Thus, it was the conclusion of the investigator that recovery from exercise is similar among lean and obese women.

Recommendations for Further Study

As a result of this study it is recommended that:

1. A similar study be done where post-exercise oxygen uptake is measured for three to 12 hours, also measuring r-value and rectal temperature as subjects are tested on several different exercise protocols, with varied durations and intensities.

2. A study be done on obese individuals where the r-value is measured for 24 hours after an one hour exercise bout done at 60 percent to 70 percent maximal heart rate and another exercise bout of one hour at 70 percent VO_2 max.

3. At least three measurements be made to approximate the resting metabolic rate of individuals in studies where recovery oxygen consumption is measured.

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APPENDIXES

APPENDIX A

CONSENT FORM DOCUMENT

Informed Consent Form

Oklahoma State University

Individual's Consent for Participation in a Research Project

"I, _____, hereby authorize or direct Dan Clements, or associates or assistants of his choosing, to perform the following treatment or procedure."

Explanation of Test

The tests you are to undergo are part of a research study. You will be weighed underwater and or pinched for skinfold thickness to determine your bodyfat percentage and lean body weight. You will also perform a maximal graded exercise test. During this test you will breath through a mouthpiece held between your lips and teeth. The mouthpiece and air hoses utilized to collect air will be secured by placing headgear around your head and forehead. The air you breath in will be room air. The air you breath out will be collected by a machine which will analyze the contents of the expired air. Twelve electrodes will be placed on the upper torso at previously established sites to help monitor the electrical activity of your heart. After the exercise test is terminated, you will continue to breath through a mouthpiece (without use of the headgear for 1 hour. Expired air will be collected at certain intervals during this rest period.

The test will take approximately 3 to 4 hours of your time from two (2) separate meetings. Information obtained from the bodyfat determination will be utilized to determine if bodyfat weight has an effect on postexercise oxygen consumption. The results will be compared with other women of similar lean body weight. Through research such as this, it is hoped that better understanding of obesity and its effects on energy expenditure will be obtained so that innovative methods of weight reduction and exercise for the obese can be substantiated.

Consent by Subject

The information which is obtained will be treated as privileged and confidential and will not be released or revealed to anyone without your express consent. The information will be used for research purposes only as a part of group data. Results will be given to you following the completion of the study.

The investigator is certified as an Exercise Test Technologist through the American College of Sports Medicine and Red Cross Certified in CPR. Every effort will be made

to minimize the possibility of a cardiac incident. In the event of a research related injury, the above researcher will be in charge and will notify an Emergency Room Physician or the subject's personal physician if necessary. Questions pertaining to the research, subject's rights and who to contact in case of research - related injury may be addressed to the investigator.

"I have read and understand the foregoing. Any questions which may have occurred to me have been answered to my satisfaction and I am aware of any risks associated with my taking the tests. I understand that I may withdraw from or discontinue my participation at any time I feel it necessary."

This is done as part of an investigation entitled: "A Comparison of Immediate Postexercise Oxygen Consumption in Lean and Obese Women."

"I may contact Daniel Clements at telephone number (404) 534-4723 or (404) 535-3399 should I wish further information about the research. I may also contact Terry Maciula, University Research Services, 001 Life Sciences East, Oklahoma State University, Stillwater, OK 74078; Telephone: (405) 744-5700."

"I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me."

Date: _____ Time _____ (a.m./p.m.)

"Signed _____"
Signature of Subject

"Witness _____"

"I certify that I have explained all elements of this form to the subject before requesting her to sign it."

"Signed _____"
Project Director

APPENDIX B

RESEARCH SUBJECT APPLICATION FORM

"A Comparison of post-cycle ergometry oxygen consumption between lean and obese women."
Research Study Application Form

NAME _____ Home Phone _____

ADDRESS _____ Work Phone _____
_____

Date of Birth _____ Age ___ Weight _____

Spouse _____ Physician _____

Medications (dose and frequency) _____
_____

FAMILY HISTORY
Coronary Disease (age) _____
Sudden Death (age) _____
Congenital Heart Disease _____

PERSONAL MEDICAL HISTORY

	yes	
Heart Attack or heart abnormalities	___	
Chest Discomfort	___	
High Blood Pressure	___	
Rheumatic fever	___	
Unusual shortness of breath	___	
Lightheadedness or fainting	___	
Pulmonary disease (asthma, etc.)	___	
Diabetes	___	
Emotional disorders	___	
Drug or Food Allergies	___	list_____
		_____
Orthopedic problems	___	
Been Pregnant within last year	___	

PERSONAL LIFESTYLE HABITS

	yes	no
Smoke Cigarettes	___	___
Exercise more than 2 days each week for the last 3 months	___	___
Weight remained within 5 pounds over last 3 months	___	___

APPENDIX C

HANDOUT TO SUBJECTS (PRETEST)

Dear _____,

This is a reminder that you are scheduled for a Graded Exercise Test and Post-Exercise Nutritional Assessment on _____ at _____ a.m.

A list of Pre-test Instructions is BELOW.

1. Do not engage in any strenuous exercise 2 days prior to the tests and no exercise the day prior to the tests.

2. Eat normally until the evening meal prior to the tests. Please follow the specific guidelines pertaining to nutrition the night prior to the test.

3. Do not eat anything the morning of the tests.

4. Remain as calm as possible the morning of the tests.

5. Bring comfortable, loose fitting exercise clothing and tennis shoes. Remember, you will get very warm for part of the test.

Should you need to reschedule due to an emergency or illness, please let me know as soon as possible. If you are sick within 5 days of the test, please let me know before the test day.

We will be performing the tests on the 4th floor of the Outpatient Services Building, in the Fit-for-Life Human Performance Lab. Please arrive on time. Thanks for your help.

Sincerely,

Daniel Clements

APPENDIX D

MAXIMAL GRADED EXERCISE TEST

CONSENT FORM

INFORMED CONSENT FOR MAXIMAL GRADED EXERCISE TEST

You will perform a graded exercise test on a bicycle ergometer. The exercise intensities will begin at a level you can easily accomplish and will be advanced in stages. We may stop the test at any time because of signs of extreme fatigue or discomfort. However, you will determine the point at which we terminate the test.

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorders of heart beat, and in rare instances, heart attack. Every effort will be made to minimize these chances through preliminary examination and by observations during testing. Emergency equipment and trained personnel are available to deal with unusual situations which may arise.

You will breath through a mouthpiece held between your lips and teeth while you exercise. A clip will be placed over your nose to stop any air from leaking through the nostrils. There is no risk at all from the breathing measurements apparatus. Some discomfort may occur around the mouth and jaw regions, however no significant problems should arise.

Any question about the procedures used in the graded exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations. Your permission to perform this graded exercise test is voluntary. You are free to deny consent if you so desire.

"I have read this form and I understand the test procedures that I will perform. I consent to participate in this test. I also verify that I understood all the questions asked about my medical history and current health status. To the best of my knowledge, I have answered the questions as accurately as possible."

_____ _____

signature of subject date

_____

signature of investigator

_____

Physicians signature

APPENDIX E

MAJOR CORONARY RISK FACTORS

Major Coronary Risk Factors according to the American College of Sports Medicine

1. History of high blood pressure (above 145/95)

2. Elevated total cholesterol/high lipoprotein cholesterol ratio (above 5)

3. Cigarette smoking

4. Abnormal resting ECG - including evidence of old myocardial infarction, left ventricular hypertrophy, ischemia, conduction defects, dysrhythmias

5. Family history of coronary or other atherosclerotic disease prior to age 50

6. Diabetes mellitus

VITA

Daniel Wayne Clements

Master of Science

Thesis: A COMPARISON OF POST-CYCLE ERGOMETRY OXYGEN CONSUMPTION BETWEEN LEAN AND OBESE WOMEN

Major Field: Health, Physical Education and Leisure

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